

Moreover, displacements of 0.53 to 0.95 metre along the west coast of Kagoshima Bay converge with those in the west and north of Sakura-jima towards an elliptical area which agrees roughly with the area of greatest depression.

Propagation of Sound-Waves.—Prof. Omori divides the sounds which accompanied the eruption into three groups: (1) the early sounds heard from about 10 a.m. to the afternoon of January 12; (2) the strong detonations from 6.30 p.m. on January 12 to 6 a.m. on January 13; and (3) the much weaker sounds of the after-explosions for about ten days following the great eruption. All these sounds were heard within two entirely detached areas, and it is remarkable how similar these areas are in form and to some extent in magnitude. The area which includes the volcano extends in each case in an easterly direction, the mean radius of the boundary being 111, 114, and 102 km. for the above three classes of sounds. The second area lies to the north of the other, and is elongated from west to east, the mean radial distance of its central line from the volcano being 195, 177, and 196 km. The width of the silent zone was 40–50 km. for the strong detonations and about 108 km. for the after-explosions, the axis of the silent zone, in both cases, being at a distance of about 120 km. from Sakura-jima. The greatest distance to which the detonations were heard is about 500 km. (or 310 miles) towards the north-east, but the air-vibrations were strong enough to shake houses and doors for about 85 km. farther in the same direction.

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THE BRITISH ASSOCIATION AT NEWCASTLE.

SECTION E.

GEOGRAPHY.

OPENING ADDRESS (ABRIDGED) BY EDWARD A. REEVES,
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THE surveying equipment of the pioneer explorer of early days, say, of from twenty to sixty years ago, usually consisted of a sextant and artificial horizon, a chronometer or watch, prismatic compass, boiling-point thermometers, and aneroid. With the sextant and artificial horizon the astronomical observation for latitude and longitude were taken, as well as those for finding the error of the compass. The route was plotted from the compass bearings and adjusted to the astronomically determined positions. The latitudes were usually from meridian altitudes of the sun or stars, and longitudes from the local mean time derived from altitudes east or west of the meridian, compared with the times shown by the chronometer, which was supposed to give Greenwich Mean Time.

The sextant, in the hands of a practical observer, is capable of giving results in latitude to within 10" or 20", provided it is in adjustment, but the difficulty is that the observer has no proper means of testing for centring and graduation errors.

The great drawback to the sextant for survey work is that it is impossible to take accurate rounds of horizontal angles with it, since, unless the points are all on the same level, the angles must be too large. It is essentially a navigator's instrument, and nowadays has been almost entirely superseded by the theodolite for land-surveying.

As regards the longitude, the difficulty was always to obtain a steady rate for the chronometer, owing principally to the unavoidable oscillations and concussions met with in transit. Formerly it was customary to observe lunar distances for getting the Greenwich Mean Time instead of trusting to the chrono-

meters, but these, even with the utmost care, are very unsatisfactory.

In more recent years the occultation of a star method of finding the Greenwich Mean Time superseded almost entirely the lunar distance, but all these so-called "absolute" methods of finding longitude are fast becoming out of date since the more general introduction of triangulation and wireless telegraphy.

Heights of land were usually obtained by the boiling-point thermometer or aneroid.

This, then, was the usual equipment of the pioneer. With such an outfit the greater part of the first mapping of Africa and other regions of the world was carried out, with results that were more or less trustworthy according to the skill of the explorer and the time and opportunities at his disposal.

In recent years considerable improvement has been made in the instruments and methods of the geographical surveyor; the introduction of the invar tape for the measuring of the base lines, the more general application of triangulation, the substitution of the theodolite for the sextant, the use of the plane-table for filling in the topographical details of the survey, the application of wireless telegraphy to the determination of longitudes, these and other improvements have all tended to greater accuracy and efficiency in geographical and topographical mapping, so that in many respects the rough approximate methods of the earlier explorers are fast being superseded by instruments and methods more in keeping with modern requirements in map-making.

Still, the principle underlying all surveying is the same, and the whole subject really amounts to the best and most accurate methods of measurement with a view of representing on a plane, on a greatly reduced scale, the leading features of a certain area of the earth's surface in their relatively correct positions; and so it resolves itself into geometrical problems of similar angles and proportional distances. This being the case, it is clear that it becomes in the main a question of correct angular and linear measurements, and all the improvements in survey methods have had for their object the increased accuracy of accomplishing this, together with greater facility for computing the results.

What we do now is exactly what was attempted by the early Greek geometers and others in ancient times, only we have far more accurate instruments. If, for instance, we compare our modern micrometer theodolite with the old scaph of the Greeks the contrast is striking, although both had the same object in view as regards taking altitudes of heavenly bodies. Many of the old instruments, in spite of their great size, were extremely rough, and the angles could only be read with approximation or to a great extent by estimation, while the theodolite, which is now generally used on geographical surveys, although it has circles of only five inches in diameter, can, by means of the micrometers, be read to 2" of arc, or even to 1" by careful estimation. This, when one comes to think of it, is a triumph of refinement, since it really means that we can measure to within about 1/80,000 part of an inch, which is something like the space occupied by 1" on the arc of a circle of 5-in. diameter. At least this is the theoretical accuracy, but in practice there are, of course, errors in sighting, setting the micrometer wires, and those arising from other sources which have to be taken into consideration.

The continued striving after greater accuracy of measurement applies not only to angular measuring instruments, but to linear distance measurement as well; and the improvements in apparatus for this purpose, could we follow them in detail, would be most interesting. From the rough methods that would suggest themselves naturally to early intelligent men,

to the modern base-line apparatus, and accurately computed sides of a geodetic triangulation, is a far cry, and the advance in this matter is certainly remarkable.

So far what I have said has had chiefly to do with some of the earlier attempts at surveying and mapping, and the instruments and methods by which these have been carried out; and I will now try to give you an outline of what has been done in comparatively recent times, and state briefly the present position of various parts of the world as regards the condition of their mapping and the survey basis upon which their maps depend.

Little by little civilised man, by his daring, his love of adventure, and the necessities of events and circumstances, has penetrated into the unexplored parts of the earth and pushed back the clouds and mists that so long shrouded them from his knowledge, until at the present time the regions that are entirely unmapped are very few indeed, and do not amount to more than about one-seventh of the whole land-surface of the globe, including the unexplored areas of the polar regions, which may be either land or water. Not content with a mere vague acquaintance, he has striven for greater accuracy, and has turned to various branches of science and called them to his aid, in order that he may obtain more correct knowledge and a better comprehension of the earth's features. To enable him to fix with definiteness the position of places upon its surface, map out the various land-forms, and obtain their accurate measurements, he has consulted the astronomer and mathematician. Commencing with the rudest instruments and measuring apparatus, these, as greater accuracy was required, have gradually been improved, until the present-day appliances and equipment of a surveyor are wonders of refinement and delicacy.

I have attempted to form an estimate of the condition of the world's surveys for 1860 and 1916; and, taking the total area of the land-surface of the earth together with the unknown parts of the Arctic and Antarctic regions which may be either land or water, to be 60,000,000 square miles, I have obtained the following results:—

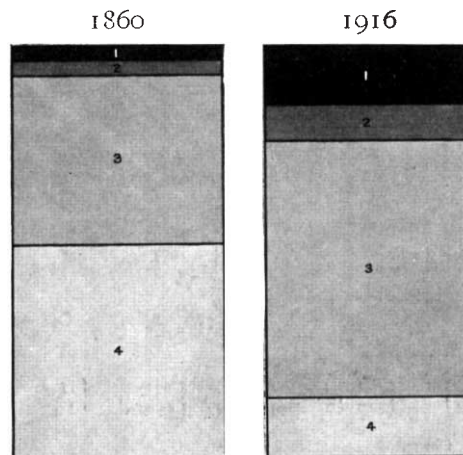
	1860	1916
	Sq. stat. miles	Sq. stat. miles
1. Mapped from accurate topographical surveys based on triangulation or rigorous traverses	1,957,755 = 0.0326 or roughly $\frac{1}{30}$	8,897,238 = 0.1482 or roughly $\frac{1}{7}$
2. Mapped from less trustworthy surveys, chiefly non-topographical	2,017,641 = 0.0336 or roughly $\frac{1}{30}$	5,178,008 = 0.0866 or just over $\frac{1}{12}$
3. Mapped from route traverses and sketches	25,024,360 = 0.4170 or roughly $\frac{2}{5}$	27,550,552 = 0.4592 or little less than $\frac{3}{4}$
4. Entirely unsurveyed and unmapped	30,997,054 = 0.5166 or just over $\frac{1}{2}$	8,280,794 = 0.1391 or little less than $\frac{1}{7}$

These proportions can perhaps be more clearly seen from the following diagram (Fig. 1), on which numbers and tintings have the same significance as on the maps and table.

From the figures here given it is plain that with the same rate of progress as that of the past sixty years or so it would take more than four hundred years more to complete the accurate trigonometrical surveying and topographical mapping of the earth's land-surface, including the parts of the polar regions that may possibly be land—that is, the 60,000,000 square miles which we have taken for this total area; but this will certainly not be the case, since the rate at which such surveys have been carried out has been greatly accelerated during recent years, owing to the rapidly increasing demands for accurate topographical maps, improvements in methods, and other causes, so that it will possibly not be half this time before all the parts of the earth's surface that are likely to be of any use to man as settlements, or capable of his

development, are properly surveyed and mapped. There are, of course, regions, such as those near the poles and in the arid deserts, that are never likely to be accurately triangulated and mapped to any extent, and it would be mere waste of time and money to attempt anything of the kind.

From its very foundation the Royal Geographical Society has had a remarkable influence on the surveying and mapping of the earth's surface, and especially those parts of it which have been previously but very imperfectly known or entirely unexplored. I think it must be admitted that this influence has increased as years have gone by, and it is no exaggeration to say that it has done more in this respect than any other body. It is therefore perhaps fitting that I should give some account of what has been accomplished, as it has a direct bearing on route-surveying and mapping by travellers and explorers. It is not only by the awarding of annual medals to explorers whose journeys have resulted in an increase to our geographical knowledge, and the more accurate surveying and mapping of little-known parts, that the society has stimulated and encouraged geographical research, but it has also assisted financially numerous expeditions, and the money thus granted has enabled many a man to carry out his explorations to a successful issue,



[FIG. 1.—Relative condition of world surveys in 1860 and 1916.]

which he otherwise could not have done for want of funds. Still more frequently has it been the case that travellers going into little-known parts of the world have been granted loans of surveying instruments which they could not otherwise have taken, and encouraged to do what mapping they found possible. Altogether 331 expeditions have been lent instruments, and about 38,500l. have been devoted to grants of money by the society to further geographical exploration and surveying.

There is still another way, by no means the least important, in which the Royal Geographical Society has done much to promote geographical surveying, and that is by providing suitable instruction in the work of surveying for travellers. It is all very well to grant money and lend instruments, but the important thing is to know how to make good use of the money and the instruments so as to take proper advantage of opportunities afforded and to produce the best surveys and maps of the regions visited. In the early days of the society a man had to pick up the requisite knowledge as best he could, but in 1879 a scheme of proper instruction was started at the suggestion of the late Sir Clements Markham, who was then one of our honorary secretaries. This had small beginnings, but in recent years has made rapid strides, until at present

it forms one of the most important parts of the society's work. This course of instruction in geographical surveying, which has now been in existence for about thirty-eight years, was first conducted by my predecessor, the late Mr. John Coles, and, since he resigned in 1900, has been under my charge. Altogether 725 surveyors and explorers have received instruction, without reckoning special large classes of forty or fifty men which during the past few years, until the outbreak of war, were sent to us by the Colonial Office to learn the more elementary parts of compass-traversing and mapping.

Now as regards the future. The demand for properly trained geographical surveyors has been steadily increasing in past years, and is likely to be still greater as time goes on. After the termination of the war there will be much work to be done, especially as regards the surveying of new boundaries, and freshly acquired districts in Africa and elsewhere; and it would be wise to make preparations for this well ahead.

The future surveyor will be in a much better position than his predecessors, not only on account of the improvements in instruments and apparatus for his work, but because, in many parts, a good beginning has been made with the triangulation to which the new surveys can be adjusted. In Asia a considerable amount of new work of this kind has been done over the frontier of India in recent years by the Survey of India, among the more important of which are the connecting of the Indian triangulation with that of Russia by way of the Pamirs, the surveys of Sir Aurel Stein, Dr. de Philippi, and others. The many boundary surveys that have been carried out in Africa, the triangulations of Egypt, the Sudan, East and South Africa, and other parts of the continent are well advanced, and will be of the utmost value to the future surveyor. One of the most important lines is the great triangulation which, it is hoped, will some day run across the continent from south to north, from the Cape to Egypt. Owing to the energies of the late Sir David Gill, this important chain of triangles has already got so far as the southern end of Lake Tanganyika; the part to the west of Uganda, near Ruwenzori, has also been finished, and it now remains to carry the chain through German East Africa and down the Nile Valley. The latter, it is hoped, will by degrees be accomplished by the Sudan and Egyptian Survey Departments, although it may be delayed for some years yet; and the former, which was to have been undertaken by the Germans, it is to be hoped will, after the war, be accomplished by British surveyors, through—not German East Africa—but newly acquired British territory. Running right through parts of Africa that are but imperfectly mapped in many districts, the stations of this triangulation will be invaluable for the adjustment of any network of triangulation for future surveys in the interior, and, indeed, has already been utilised for the purpose.

The carefully carried out boundary surveys between various countries of South America will be of the greatest assistance in future exploration and survey in the interior of that continent, wherever they are available, while the Survey Departments of Canada and the United States are doing excellent work and extending their surveys far into the imperfectly mapped regions of North America. So, altogether, the surveyor of the future will soon have a good foundation of trustworthy points to work from. It is important to remember that running a chain of triangles across a country, though important as a framework, does not constitute a map of the country; and what is wanted is a series of good topographical maps, based upon triangulation, showing the leading features with

sufficient accuracy for the purposes of ordinary mapping, so that on scales of 1 : 250,000, or even 1 : 125,000, there is no appreciable error.

As regards instruments, the astrolabe à prisme is being increasingly used for taking equal altitude observations with most excellent results, but at the present time the 5-in. transit micrometer theodolite, already referred to, is perhaps all that is required for general work. It has now been thoroughly tested and found most satisfactory. As regards smaller instruments, there is the 4-in. tangent-micrometer theodolite, and for rapid exploratory survey, where weight is a great consideration, a little 3-in. theodolite has been found useful.

For base-line measurement the invar tape should be taken on all serious work, and for filling in the topographical features a good plane-table is doubtless the instrument to use. In mountainous regions and in some other special conditions photographic surveying doubtless has a future before it, and in military operations when the photographs are taken from aircraft it has proved itself invaluable; but in ordinary surveying it is, I think, not likely to take the place of well-established methods. The introduction of wireless telegraphy for the determination of longitude is likely to increase in usefulness. Good examples of the work done with it have lately been given in the *Geographical Journal* and elsewhere.

FORTHCOMING BOOKS OF SCIENCE.

AGRICULTURE.

Macmillan and Co., Ltd.—The Potato, Prof. A. W. Gilbert and others, illustrated; The Strawberry in North America, S. W. Fletcher, illustrated; A Manual of Fruit Diseases, Prof. L. R. Hesler, illustrated; A Manual of Dairy Products, Prof. W. A. Stocking, illustrated; The Pruning Manual, Prof. L. H. Bailey, new edition, illustrated. *Oxford University Press.*—Agriculture in Oxfordshire, the first of a series of monographs on the English Counties, prepared by the Institute for Research in Agricultural Economics in the University of Oxford, illustrated.

ANTHROPOLOGY AND ARCHÆOLOGY.

F. Alcan (Paris).—Les Races et les Nationalistes en Autriche-Hongrie, Prof. Auerbach. *G. Bell and Sons, Ltd.*—Modern Man and His Forerunners: a Short Study of the Human Species, Living and Extinct, Dr. H. G. F. Spurrell, illustrated; Savage Survivals, J. H. Moore, illustrated. *Cambridge University Press.*—Jataka Tales, H. T. Francis and E. J. Thomas, illustrated; The Ancient Cross Shafts at Bewcastle and Ruthwell, enlarged from the Rede Lecture delivered before the University of Cambridge on May 20, 1916, by the Right Rev. Dr. G. F. Browne, illustrated. *Longmans and Co.*—The Folk-Element in Hindu Culture: a Contribution to Socio-Religious Studies in Hindu-Folk Institutions, Prof. Benoy Kumar Sarkar, assisted by Hemendra K. Rakshit. *John Murray.*—The Ages of Man, C. Sayle; The Lost Cities of Ceylon, G. E. Mitton, illustrated. *Oxford University Press.*—The Drama of Savage Peoples, L. Havemeyer. *Seeley, Service and Co., Ltd.*—Prehistoric Man and His Story, Prof. G. F. Scott Elliot, illustrated.

BIOLOGY.

F. Alcan (Paris).—L'Évolution des Plantes, Prof. N. Bernard; Théorie de la Contre-évolution, Dr. Langer. *D. Appleton and Co.*—The Book of Forestry, F. F. Moon. *E. Arnold.*—Arboreal Man, Prof. F. Wood Jones, illustrated; the Migrations of Fish, Prof.